

AD-A068 480

NAVAL AIR DEVELOPMENT CENTER WARMINSTER PA AIRCRAFT --ETC F/G 6/16
THERMAL CONDUCTION EFFECTS IN HUMAN SKIN. II. EXPERIMENTAL VALI--ETC(U)
JAN 79 A M STOLL, M A CHIANTA

CPSC-77-0091

UNCLASSIFIED

NADC-79034-60

NL

/ OF |

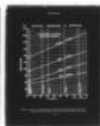
AD
A068480



END
DATE
FILMED

6 --79

DDC



REPORT NO. NADC-79034-60

LEVEL III

11

AO 68479



AD A068480

**THERMAL CONDUCTION EFFECTS IN HUMAN SKIN:
II. EXPERIMENTAL VALIDATION AND APPLICATION
OF DATA IN SELECTION OF MATERIALS**

A.M. Stoll, M.A. Chianta and J.R. Piergallini
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

15 JANUARY 1979

PHASE REPORT
AIRTASK NO. WF51-523-000
Program Element 62758N

INTERAGENCY AGREEMENT NO. CPSC IAG-77-0091

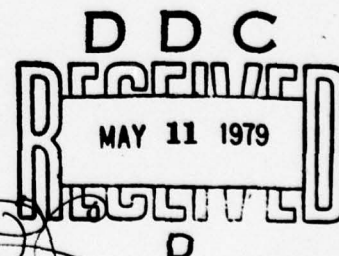
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DDC FILE COPY

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D.C. 20361

and

U.S. CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207



79 05 09 006

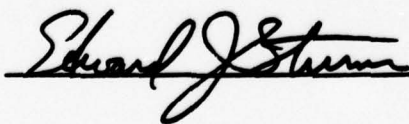
NOTICES

REPORT NUMBERING SYSTEM - The numbering of technical project reports issued by the Naval Air Development Center is arranged for specific identification purposes. Each number consists of the Center acronym, the calendar year in which the number was assigned, the sequence number of the report within the specific calendar year, and the official 2-digit correspondence code of the Command Office or the Functional Directorate responsible for the report. For example: Report No. NADC-78015-20 indicates the fifteenth Center report for the year 1978, and prepared by the Systems Directorate. The numerical codes are as follows:

CODE	OFFICE OR DIRECTORATE
00	Commander, Naval Air Development Center
01	Technical Director, Naval Air Development Center
02	Comptroller
10	Directorate Command Projects
20	Systems Directorate
30	Sensors & Avionics Technology Directorate
40	Communication & Navigation Technology Directorate
50	Software Computer Directorate
60	Aircraft & Crew Systems Technology Directorate
70	Planning Assessment Resources
80	Engineering Support Group

PRODUCT ENDORSEMENT - The discussion or instructions concerning commercial products herein do not constitute an endorsement by the Government nor do they convey or imply the license or right to use such products.

APPROVED BY:



DATE:

3-15-79

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 NADC-79034-60	2. GOVT ACCESSION NO. Effects	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 Thermal Conduction in Human Skin. II. Experimental Validation and Application of Data in Selection of Materials.		5. TYPE OF REPORT & PERIOD COVERED Phase Report.
7. AUTHOR(s) 10 A.M./Stoll, M.A./Chianta J.R./Piergallini		8. CONTRACT OR GRANT NUMBER(s) 15 CPSC-77-0091
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aircraft & Crew Systems Technology Directorate Naval Air Development Center Warminster, PA 18974		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AirTask WF51-523-000, P.E. 62758N; Interagency Agreement CPSC IAC-77-0091
11. CONTROLLING OFFICE NAME AND ADDRESS Refer to Block 18		12. REPORT DATE 11 15 January 1979
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 16 F51523 17 WF51523000		13. NUMBER OF PAGES 12
15. SECURITY CLASS. (of this Report) UNCLASSIFIED 12/18p		18. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Naval Air Systems Command Department of the Navy Washington, D.C. 20361 U.S. Consumer Product Safety Commission Washington, D.C. 20207		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Blistering Temperature Thermal pain and blister on contact Prediction of injurious temperatures		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Experimental production of threshold blisters at material temperatures and contact times predicted from measurements of pain thresholds validated the concept underlying this study, that is, that the relationship between pain and blister thresholds established earlier for radiant and for convective heating could be extended into the region appropriate to conductive heating to provide a simple factor by which to convert pain threshold contact times to threshold blister times. From the successful demonstration of this		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

393 532

JOB

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AUTHORIZATION BY CTR DDO UNANNOUNCED JUSTIFICATION			DUTY STATUS DUTY STATUS <input checked="checked" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
BY _____ DISTRIBUTION/AVAILABILITY CODES REG. AVAIL. AND/OR SPECIAL			
A			

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

TABLE OF CONTENTS

	Page
INTRODUCTION	2
METHOD AND RESULTS	2
APPLICATION	8
SUMMARY AND CONCLUSION	11
REFERENCES	12
ACKNOWLEDGMENT	12
LIST OF FIGURES	1

FIGURES

1	Prediction of material temperatures required to cause threshold blisters from 0.3 sec contact by extrapolation of reciprocal of exposure time vs material temperature along blister parameter	3
2	Verification of blister effect in contact with aluminum at predicted material temperature. Predicted T = 132°C. .	5
3	Verification of blister effect in contact with Masonite at predicted material temperature. Predicted T = 195°C. .	6
4	Verification of blister effect in contact with Hercuvit at predicted material temperature. Predicted T = 149°C. .	7
5	Verification of blister effect in contact with glass at predicted material temperature. Predicted T = 159.6°C. .	9
6	Material temperatures and properties as functions of pain and blister at given contact times and minimal epidermal thickness	10

INTRODUCTION Part I of this study provided the experimental data required for the prediction of the maximum permissible temperature of any material for non-injurious contact with bare skin. Part II, the present report, describes the use of these data to predict material temperatures which will cause blisters virtually on contact and the experimental verification of these predictions.

METHOD AND RESULTS The raw data obtained by measurement of pain threshold time at various temperatures of each material used were plotted as shown in Part I, Figures 4 and 5. From these averaged, best-fit pain threshold curves, similar curves for threshold blister temperature-time parameters were calculated by multiplying by the constant 2.5 relating pain threshold time to threshold blister time at the same energy absorption rate. These data, converted to reciprocal time, were plotted on semi-log paper against corresponding material temperature and extrapolated to the 0.3 sec level. Figure 1 presents these extrapolations for the subject having the thinnest epidermis.

Since the predicted values were now two operations removed from the observed data, to verify the predicted blister temperature, each material was heated to the indicated level and the back of a finger (representing minimal epidermal thickness, approx. 60μ) was brought in contact with the specimen for 0.3 sec as closely as the subject could approximate. As might be expected, some contacts were too short and some too long but for all practical purposes it was possible to bracket the threshold blister value quite accurately. A minimal blister occurring within 24 hr after exposure indicated attainment of the correct temperature and time. Only four of the six experimental materials were used in this procedure; steel was omitted because of its close similarity to aluminum, and Teflon was omitted because at the high temperature required (177°C) it expanded excessively, bulging away

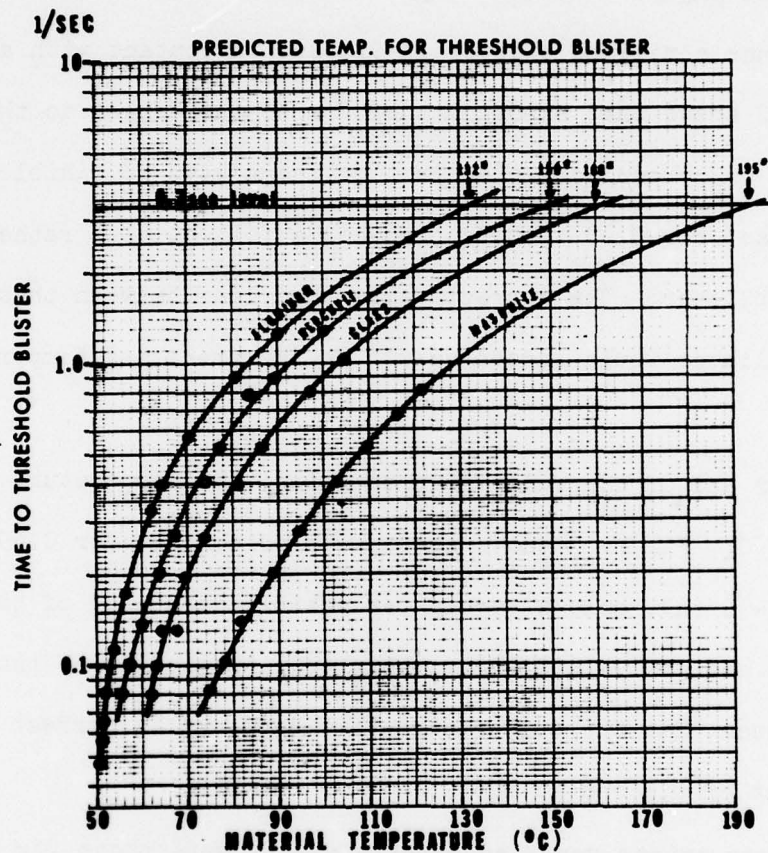


FIGURE 1 - Prediction of material temperature required to cause threshold blisters from 0.3 sec contact by extrapolation of reciprocal of exposure time vs material temperature along blister parameter.

from the heater plate and causing uncertainty in the actual temperature of the specimen at the moment of contact. However, the remaining four materials provided sufficient span in thermal properties to establish the blister end points at the extremes and key locations throughout the range of properties of the materials used.

It is seen in Figure 1 that a temperature of 132°C is indicated as that required to produce a minimal blister in 0.3 sec in contact with aluminum (6061-T6 alloy). Figure 2 shows that exposing the back of the finger to the aluminum at 132° for 0.2 sec (A) produced a transient erythema with no visible effect after 24 hr while contact for 0.45 sec (B) produced a full blister rather than the desired minimal blister. The correct value then lies between these times indicating that a minimal blister would indeed result at the predicted temperature on 0.3 sec contact.

At the other end of the range of properties, the temperature indicated for Masonite was 195°C . Figure 3 shows the effect of contact for 0.29 sec with Masonite at 194.4°C (A), only a barely perceptible darkening of the skin, and in contact for 0.35 sec at 194.6°C (B), a blister slightly larger than minimal resulted, again good evidence that the temperature-time exposure is correct for the desired end point of 0.3 sec at 195°C .

The two other points verified experimentally were those for Hercuvit (106)*, a ceramic used in range tops, and for glass, and these too yielded similar results: The predicted temperature for Hercuvit was 149°C ; erythema resulted at 149.3°C and 0.20 sec (A), and full blister at 149.6°C and 0.29 sec contact (B).

*Sample supplied courtesy of PPG Industries.



FIGURE 2 - Verification of blister effect in contact with aluminum at predicted material temperature. Predicted T = 132°C
A. 132°C for 0.20 sec = Transient erythema
B. 132°C for 0.45 sec = Full blister



FIGURE 3 - Verification of blister effect in contact with Masonite at predicted material temperature. Predicted T = 195°C
A. 194.4°C for 0.29 sec = discoloration, no blister
B. 194.6°C for 0.35 sec = blister, slightly larger than threshold



FIGURE 4 - Verification of blister effect in contact with Hercuvit at predicted material temperature. Predicted $T = 149^{\circ}\text{C}$
A. 149.3°C for 0.20 sec = transient erythema
B. 149.6°C for 0.29 sec = full blister

For glass the predicted temperature was 159.6°C . Trials at 160° for 0.46 sec and 0.29 sec produced full blisters; at 0.26 sec and 157°C , Figure 5 (A), only erythema followed while at exactly 0.30 sec and 158°C (B) the definitive standard threshold blister was obtained.

This series of exposures indicates that the blister end point is quite precise and that the extrapolation is usually within about 1°C of the correct value. Furthermore, temperatures corresponding to blister-producing contact times longer than 0.3 sec can be predicted even more reliably as the extrapolated distances become shorter, thus it is expected that the temperatures predicted for 0.5 sec contact will be within 0.5°C of the true value although these were not verified experimentally.

APPLICATION The working chart for finding maximum permissible temperature for safe thermal contact with skin of minimal epidermal thickness is shown in Figure 6. Using coordinates described by Wu (1), material temperature is plotted against material properties to the parameter of pain threshold at 1.0 and 3.0 sec and extrapolated values for "instantaneous" (0.3 sec) pain and "instantaneous" (0.3 sec) blister as verified experimentally.

To use this chart for identification of the maximum safe temperature of a given material, the engineer need know only the thermal properties of the proposed material, i.e., thermal conductivity (k), density (ρ) and specific heat (c). One then locates on the abscissa the appropriate value calculated as the reciprocal of the square root of the thermal inertia, $1/\sqrt{k\rho c}$. The corresponding maximum permissible temperature is found as the coordinate on the instantaneous blister (0.3 sec) parameter minus 1°C for minimal safety, or more for greater safety, the



FIGURE 5 - Verification of blister effect in contact with glass at predicted material temperature. Predicted $T = 159.6^{\circ}\text{C}$
A. 157°C for 0.26 sec = transient erythema
B. 158°C for 0.30 sec = threshold blister

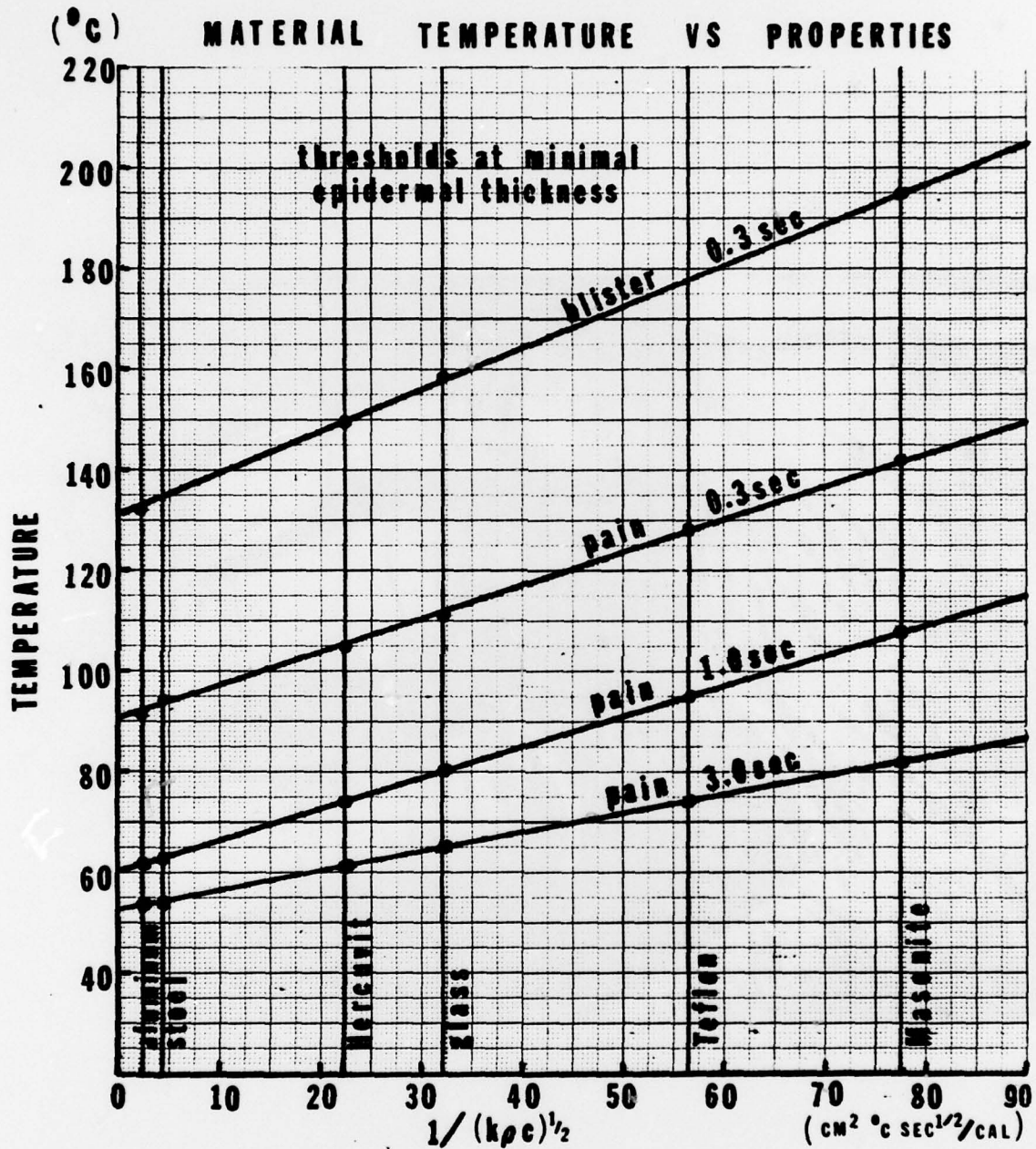


FIGURE 6 - Material temperatures and properties as functions of pain and blister at given contact times and minimal epidermal thickness.

latter margin at the discretion of the engineer. In considering the safety margin, it should be borne in mind that the accuracy of these data as applied generally should not be expected to be better than $\pm 10\%$, the limits of the original data.

Should it be desirable to use the chart for selection of a safe material, the procedure is used in reverse order, i.e., the maximum anticipated temperature plus the safety margin is located on the ordinate, the coordinate found on the blister line and the corresponding thermal property value read off the abscissa. A search may then be made to identify a suitable material having the proper thermal inertia.

Additionally, if the material is mandated by the function it must perform, e.g., a metal for strength, and it is not possible to hold the temperature below the indicated injurious level, it is possible to select an insulative coating material to provide a safe surface. The thickness of the coating can be calculated from the thermal properties of both materials by use of heat flow equations for two-layer walls (2) and the "safe" temperature of the composite determined from the present chart. Trial specimens may be made up and tested for efficacy by means of the pain threshold determination technique described in Part I.

SUMMARY AND CONCLUSION Experimental production of threshold blisters at material temperatures and contact times predicted from measurements of pain thresholds validated the concept underlying this study, that is, that the relationship between pain and blister thresholds established earlier for radiant (3) and for convective (4) heating could be extended into the region appropriate to conductive heating to provide a simple factor by which to convert pain threshold contact times to threshold blister times. From the successful demonstration of this thesis, it is concluded that extrapolation of converted pain threshold temperature-

time values determined empirically constitutes a reliable means of predicting maximum permissible temperatures of materials for safe contact with bare skin. The information so derived pertinent to areas of minimal epidermal thickness is presented in chart form suitable for use in preselection of thermally safe construction and manufacturing materials.

REFERENCES

1. Wu, Y-C Material properties criteria for thermal safety. J. of Materials JMLSA, Vol 7, No. 4, 573-579, Dec 1972.
2. Griffith, M.V. and G.K. Horton. The transient flow of heat through a two-layer wall. Proc. Phys. Soc. (London) 58:481, 1946.
3. Stoll, A.M. and M.A. Chianta. Method and rating system for evaluation of thermal protection. Aerospace Med. 40:1232-1238, 1969.
4. Stoll, A.M. and M.A. Chianta. Burn production and prevention in convective and radiant heat transfer. Aerospace Med. 39:1097-1100, 1968.

Work supported by the Naval Air Systems Command and the U.S. Consumer Product Safety Commission. The voluntary informed consent of the participating subjects was obtained as requested by existing U.S. Navy regulations.

ACKNOWLEDGMENT The excellent technical assistance of Mr. Dom Zaccaria is gratefully acknowledged.

D I S T R I B U T I O N L I S T (C o n t ' d)

	<u>No. of Copies</u>
NASA-Lewis, Cleveland, OH	1
NASA-Ames, Moffett Field, CA	1
NASA Scientific & Tech. Info. Facility, College Park, MD . . .	5
(3 for retention)	
(1 for S-AK/DL)	
(1 for NASA Rep.)	
Library of Congress, Washington, DC	2
(1 for Bibliographies Section)	
(1 for Science & Tech. Div.)	
HQ, Naval Material Command (034-D), Washington, DC	1
COMOPTEVFOR	1